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MINISTRY OF AVIATION

AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT

BOSCOMBE DOWN

NOISE HAZARDS ASSOCIATED WITH AIRCRAFT OPERATION WITH PARTICULAR REFERENCE TO T.S.R.2 AT BOSCOMBE DOWN

[U]

BY

M. BEENY AND A. H. DUNCAN
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Report No. AAEE/Tech/300/Eng.
22nd February 1965

**AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT
BOSCOMBE DOWN**

Noise hazards associated with aircraft operation with particular reference to T.S.R.2 at Boscombe Down

by

M. Beeny and A. H. Duncan
Engineering Division

A. & A.E.E. Ref: ABN/72/05
Period of trials: October 1964 - January 1965

Summary

This report describes in general terms how the aircraft noise hazard is being dealt with at the Aeroplane and Armament Experimental Establishment at Boscombe Down. It reprints W. Burns' damage risk criteria, and examines recent T.S.R.2 noise level measurements against those criteria. Recommendations are made to minimise the hazard.

This report is issued with the authority of

J R Bird
Air Commodore,
Commandant, A. & A.E.E.

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/1. Introduction ...

1. Introduction

1.1 The nuisance value of noise from aircraft has been dealt with by many writers but few have dealt with the more serious aspects of aircraft noise - noise levels of such severity, or of such duration, or both, as to be a probable cause of deafness or more serious injury to health. The present report examines this health hazard by bringing together two separate streams of information, one concerning the human being and the amount and kind of noise he can stand without deafness or other injury, and the other concerning the intensity and duration of noise likely to be experienced in the vicinity of aircraft, especially during take-off. (Sonic bangs are not considered here).

As regards information of the first kind, research has been going on in many countries for some years. A number of differing criteria have been published and there is the prospect that soon there will be an agreed International standard indicating the maximum daily dose of noise the majority of human beings can endure throughout their working life without risk of significant deafness throughout the speech frequencies.

As regards noise measurements on aircraft, interest has until recently centred mainly on the maximum noise intensity on take-off and landings and how this should be measured. Important though that is, there is now a clear need, if deterioration in hearing is to be avoided, to pay attention also to the duration of the noise as well as its loudness. This has been done with recent measurements made at A. & A.E.E. during the ground running and take-off of the T.S.R.2.

1.2 Although firm conclusions cannot be drawn until we have both a generally agreed standard and considerably more data from ground running and take-off from the T.S.R.2 and other aircraft, it was thought worthwhile at this early stage to make an attempt to bring together these two streams of information to show the approach and method, and to draw tentative conclusions. The particular aim was to determine what safety precautions should be taken at Boscombe Down to minimise the hazard from the T.S.R.2 and other noisy aircraft. It is likely, however, that the approach and the results will be of value as a guide to the safe conduct of flying generally; and they may also indicate ways in which freedom from noise hazards may be ensured in other noisy industrial occupations or areas.

2. Available Data

2.1 Noise tolerance limits

It is convenient to consider human tolerance to noise in two ways, corresponding to two different but fairly well defined risks, namely:-

(i) Immediate effects of sudden very loud noise, subsequently referred to as "Class 1 risk", and

(ii) delayed or cumulative effect (e.g. permanent deafness) of prolonged or repeated noise, subsequently referred to as "Class 2 risk".

These are discussed below.

2.2 The Class 1 Risk

It is commonly known that a sudden very loud noise, e.g. an explosion, can cause permanent damage to the ears, or such physical pain or fright as will upset any normal human being in the execution of a simple task (e.g. driving a car, or climbing a ladder) and thus indirectly, but hardly less certainly, lead to serious injury. Sudden exposure of an individual to a loud noise from which he had been shielded has a similar effect. This risk clearly increases with the loudness of the noise, and

for our present purposes all noises above 120 dB are taken as a Class 1 risk. This is rather an arbitrary choice based on the fact that 120 dB is accepted as the threshold of feeling. However there is evidence (Ref. 1) that with adequate forewarning, an expected noise of short duration as high as 155 dB can be experienced by some people without permanent damage.

2.3 The Class 2 Risk

For some considerable time it has been appreciated that long term exposure to noise can bring about a deterioration in hearing. This problem has been considered by workers in Great Britain, Japan, Sweden, U.S.A., U.S.S.R. and other countries (Ref. 2). It had been realised that many factors are involved some of which are ill defined, such as the difficulty in specifying the degree of deafness acceptable, and the proportion of people to which the standard should apply. Furthermore although the majority of workers have only considered hearing losses in the frequencies which make up everyday speech it is arguable that any damage which would detract from the enjoyment of music should be unacceptable. However, for this report and for current use the most up to date criteria, that of W. Burns (Ref. 3), has been accepted and is reprinted at Tables 1 and 2 below from the notes by Surgeon Commander R.R.A. Coles, R.N. These criteria are based on an expected average hearing loss,

(a) at a frequency of 4 kilocycles/second a loss of 15 decibels for the average man after 10 years,

(b) at a frequency of 2 kilocycles/second a loss of 10 decibels for the average man after 30 years.

TABLE 1

Centre-frequency of Octave Band (c/s.)	Damage risk Criterion (dB) for a normal working week (5 days of 8 hours)
63 (or Low-pass)	97
125	91
250	87
500	84
1,000	82
2,000	80
4,000	79
8,000 (or High-pass)	78

TABLE 2

For 8 hours per day, 5 days per week - add 0 dB to D.R.C. levels of Table 1
For 4 hours per day, 5 days per week - add 3 dB to D.R.C. levels of Table 1
For 2 hours per day, 5 days per week - add 6 dB to D.R.C. levels of Table 1
For 1 hour per day, 5 days per week - add 9 dB to D.R.C. levels of Table 1
For 30 mins. per day, 5 days per week - add 13 dB to D.R.C. levels of Table 1
For 15 mins. per day, 5 days per week - add 19 dB to D.R.C. levels of Table 1
For 7 mins. or less per day, 5 days per week - add 25 dB to D.R.C. levels of Table 1

/2.4 ...

2.4 For convenience the attenuation achieved by the standard ear protectors Mk. III is shown in Fig. 1.

2.5 Recordings of T.S.R.2 aircraft noise

In our earlier report (Ref. 4) the measured sound pressure levels for the T.S.R.2 while ground running and during the take-off have been published. In addition to these figures the recording of the sound pressure level against time at an observer position during the sixth take-off is used. The sound pressure levels for the take-offs are reproduced in Fig. 2 and Fig. 8. In both cases the undercarriage was not retracted and aircraft speed did not exceed 250 knots, and reheat was cancelled at an early stage.

2.6 Computation of sound pressure levels at observer positions

The time and position of the aircraft during the take-off was determined from cine photographs. This information and the sound pressure levels during ground running have been used with a computer programme to produce plots of sound pressure level against time for various hypothetical observer positions. To compute these curves an attenuation of 8 dB per double distance (i.e. the sound pressure level is reduced by 8 dB every time the distance from the source is doubled) from the 100 yds. circle ground running results, with a 6 dB per double distance attenuation for when the aircraft is airborne (i.e. above approximately 10° in elevation from the observer), has been used. These attenuation values were measured in tests here, earlier, the results of which have not been published.

Fig. 3 shows the computed time history of the sound pressure level at the observer position at which the recording at Fig. 2 was actually made and Fig. 9 shows the computed value for Fig. 8. The agreement is within the experimental error of measurement. Other computed time histories of sound pressure level are shown in Fig. 4, 5, 6 and 7. These computed time histories of sound pressure level are used to examine the Class 2 risk.

3. Deductions from the data

3.1 To examine the Class 1 risk further, noise contours (i.e. lines through all points having the same noise levels) have been prepared assuming that the aircraft passes over the end of the runway at 500 ft. in an emergency climb of only 5°, admittedly a severe assumption. The last two diagrams give the result.

These contours may be overlaid onto any airfield map to consider possible Class 1 risk. A map of the Boscombe Down Area is enclosed.

3.2 The Class 2 risk for ground staff or observers has been assessed for the two main conditions of practical interest, namely,

(a) ground running of engines (without muffler)

(b) take off.

The percentage of the maximum permissible daily dose which such observers would get has been computed by the method of Appendix I.

As regards ground running, we have considered the case of observers at 100 yards radius from the aircraft jet pipe exit. (This figure is chosen because it is the basis of the safety measures currently in force for the T.S.R.2 at Boscombe Down). In Table 3 we give the permissible endurance time per day for such observers, both with and without standard Mk. 3 ear defenders, if Class 2 risk is to be avoided.

As regards take-off, various possible observer positions alongside the runway have been considered and Table 4 gives the results in terms of the percentage of the allowable daily dose of noise which each take-off would give to the observer. Here the observer is assumed to be without ear defenders; with ear defenders the received dose is assessed as insignificant.

/Table 3 ...

TABLE 3

Engine Condition	Angular position around aircraft from the nose	Endurance time per day with no ear protection	Endurance time per day with Mk. III ear defenders
One engine running at 100% "dry" i.e. without reheat.	45° 90° $112\frac{1}{2}^\circ$ 135° $157\frac{1}{2}^\circ$	47 minutes 25 minutes 7 minutes 2 minutes 3 minutes	No limit No limit 38 minutes 11 minutes 17 minutes
One engine running with full reheat.	45° 90° $112\frac{1}{2}^\circ$ 135° $157\frac{1}{2}^\circ$	12 minutes 6 minutes 2 minutes $\frac{3}{4}$ minute 1 minute	2 hours 38 minutes 9 minutes 5 minutes 6 minutes

TABLE 4

Observer's distance from starting end of runway	Observer's offset distance from C/L of runway	Percentage of day's dose
4,680 ft.	300 ft.	3.1%
4,680 ft.	500 ft.	2.5%
4,680 ft.	1,000 ft.	1.9%

4. Discussion

4.1 Noise measurement and the hazards from noise are not at present exact branches of science. Not only are the human tolerance criteria to a degree tentative but the aircraft noise data which have been examined in the light of the criteria are very limited. Steps are being taken to put the matter on a firmer footing by making further measurements of the T.S.R.2 and other aircraft with more emphasis than formally on the duration of high noise.

4.2 Measurements at the Establishment and elsewhere have shown that higher noise levels than expected can be experienced due to refraction, reflection, wind and other meteorological factors. The magnitude of these effects is at present uncertain and may be large. For this reason conclusions drawn in this report must be regarded as tentative, and the recommendations made are biased on the side of safety.

4.3 In paragraph 3.1 it is shown how the Class 1 risk may be examined with the map overlay for the take-off, and with a similar overlay for the running-up site. The detailed application lies very much with Supervisors and Section Leaders. As a general comment it can be said that on the Boscombe Down airfield a number of locations will experience noise in excess of 120 dB (the threshold of feeling) during a T.S.R.2 take-off. These include the fire engines at their normal airfield position, the air traffic control caravan, traffic waiting at the lights on the south side of the main runway, and any maintenance or other personnel caught inadvertently within the 120 dB contour. But as all these people will, by the nature of their work and training, be expecting aircraft noise the Class 1 risk is probably not significant in most cases. Under certain conditions and at, for instance, the air traffic control caravan, noise levels of 140 dB might be experienced, and this could seriously interfere with the efficiency of an operator.

/It ...

It will be noticed, however, that a low take-off as might arise with one engine out, or an overshoot, can extend the 140 dB contour well over the public highways beyond the runway end. This could produce a serious Class 1 risk. The present warning notices facing passers-by on public roads near airfields should perhaps be augmented.

4.4 An examination of Tables 3 and 4 shows that unless the number of take-offs of the T.S.R.2 and other noisy aircraft should rise considerably above the present average for Boscombe Down there is unlikely to be any significant Class 2 risk from this cause. This situation may be taken as typical of any Experimental Establishment in normal times though the position would be entirely different with civil aircraft of similar noise output at a busy airport. The improbability of a Class 2 risk from take-offs at Boscombe Down is welcome though a little surprising. A check will be needed as the T.S.R.2 is developed and take-off weight and re-heat temperature are raised.

4.5 When we look at the cumulative effect of engine running on the ground, the principal Class 2 risk, the position is far less satisfactory. There is clearly a high probability of Class 2 risk near the 100 yard circle during engine running out of a noise muffler. It had previously been generally accepted that the 100 yard radius safety circle was adequate protection with ear defenders but Table 3 shows this is not so. A danger area of greater diameter, to include all noise above 120 decibels, should be established, or greater use made of mufflers, or both.

4.6 The effort required to continuously record noise, and to analyse and integrate it to assess the Class 2 risk, has emphasised the need for a handy portable noise dose meter. Fig. 10 shows the A. & A.E.E. prototype noise dose meter which was hastily evolved for this work, and which is now being developed commercially. By intelligent use of such instruments the hearing conservation measures currently in force could be considerably strengthened.

4.7 The figures in Table 3 have been computed for fixed positions radially 100 yards from the aircraft. Because maintenance crews move about during engine running, Fig. 3 can only be used as a guide and as these people are exposed to high noise levels, the only reliable method of checking the dose is by using individual dose meters.

4.8 Audiometric testing of individuals has been in force at A. & A.E.E. for some months and should clearly continue. By combining results thereby obtained with those coming available later from noise dose meters the damage risk criteria can in due course be defined more accurately, and hearing conservation measures put on a more reliable footing generally.

5. Recommendations

5.1 Discussions should be continued aimed at drafting effective and practical safety regulations covering possible noise hazards. Meanwhile, supervisors and individual workers should continue to be made aware of their responsibility to avoid noise hazards.

5.2 Regular audiometric checks on personnel should be continued, more frequently on those exposed to high intensity noise.

5.3 Noise measurements should be taken in air traffic control caravans, and in any other place likely to be excessively noisy, to determine more exactly the noise levels.

5.4 The adequacy of warning notices to passers-by on public highways adjacent to airfields should be reviewed.

5.5 Noise should be monitored continuously at numerous points on airfields and on individuals who work there. Suitable meters should be developed and provisioned for this.

/5.6 ...

5.6 For ground running of all noisy aircraft a danger boundary should be defined and physically marked. It is recommended that this boundary includes the 120 dB contour. Within this boundary at least Mk. III ear defenders must be worn and hearing conservation practised.

5.7 More extensive use of engine noise mufflers during ground running should be encouraged.

5.8 Work should continue to ascertain the probable noise dose for T.S.R.2 take-off which ground staff may experience, covering the wide range of loading and engine conditions of the T.S.R.2 as it develops.

Acknowledgement

It is desired to acknowledge the helpful co-operation given by the British Aircraft Corporation in carrying out the work covered by this report.

REFERENCES

Ref. No.	Title, etc.
1	W.A.D.C. Report TR 52-204, 1953.
2	P.E.R.A. Report No. 125, 1964.
3	Hearing and Noise, Burns, W. 1965.
4	A. & A.E.E. Boscombe Down Report Tech/281/Eng.

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Table V

T.S.R.2 -

Maximum permissible recommended exposure times on a circle of 100 yds. radius about the aircraft during engine runs at 100% max. power without reheat

One Engine 100% Dry

Octave Band Cycles/sec.	Sound Pressure Level dB	45° Safe Endurance Time - Secs. No Protection x 10^3 seconds	45° Safe Endurance Time - Secs. Wearing Ear-Defenders	Sound Pressure Level dB	90° Safe Endurance Time - Secs. No Protection x 10^3 seconds	90° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^4 seconds
37.5 : 75	94	81.0	-	99	25.5	6.0
75 : 150	93	23.0	-	98	7.2	4.2
150 : 300	90	16.0	-	98	2.5	-
300 : 600	90	8.2	-	96	2.8	-
600 : 1,200	89	5.9	-	97	1.5	-
1,200 : 2,400	90	3.1	-	95	1.5	-
2,400 : 4,800	89	2.8	-	93	1.6	-
4,800 : 9,600	86	4.6	-	90	2.1	-

Octave Band Cycles/sec.	Sound Pressure Level dB	112½° Safe Endurance Time - Secs. No Protection x 10^2 seconds	112½° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds	Sound Pressure Level dB	135° Safe Endurance Time - Secs. No Protection x 10^2 seconds	135° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds
37.5 : 75	112	17.0	2.9	124	4.2	0.64
75 : 150	111	9.0	2.3	121	2.9	0.70
150 : 300	109	6.7	32.0	119	2.1	3.2
300 : 600	107	6.1	-	119	1.6	26.0
600 : 1,200	107	4.5	-	117	1.5	61.0
1,200 : 2,400	106	4.2	-	117	1.2	60.0
2,400 : 4,800	104	4.4	-	114	1.4	-
4,800 : 9,600	104	4.2	-	114	1.5	43.0

Octave Band Cycles/sec.	Sound Pressure Level dB	157½° Safe Endurance Time - Secs. No Protection x 10^2 seconds	157½° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds
37.5 : 75	119	7.5	1.2
75 : 150	118	4.1	1.0
150 : 300	115	3.4	8.0
300 : 600	116	2.2	51.0
600 : 1,200	114	2.1	-
1,200 : 2,400	115	1.5	96.0
2,400 : 4,800	110	2.[illegible]	-
4,800 : 9,600	111	1.9	38.0

Table VI

T.S.R.2 -
Maximum permissible recommended exposure times on a circle of 100 yds. radius about the aircraft during engine runs and after-burner

One Engine With Full Reheat

Octave Band Cycles/sec.	45° Sound Pressure Level dB	45° Safe Endurance Time - Secs. No Protection x 10^2 seconds	45° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds	90° Sound Pressure Level dB	90° Safe Endurance Time - Secs. No Protection x 10^2 seconds	90° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds
37.5 : 75	108	32.0	7.2	113	15.1	2.3
75 : 150	106	16.0	7.2	111	9.0	2.3
150 : 300	107	8.4	50.0	112	4.6	16.0
300 : 600	104	8.7	-	111	3.9	-
600 : 1,200	101	9.2	-	109	3.7	-
1,200 : 2,400	101	7.5	-	106	4.2	-
2,400 : 4,800	99	8.0	-	105	4.0	-
4,800 : 9,600	97	9.3	-	103	4.6	-

Octave Band Cycles/sec.	112½° Sound Pressure Level dB	112½° Safe Endurance Time - Secs. No Protection x 10^2 seconds	112½° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds	135° Sound Pressure Level dB	135° Safe Endurance Time - Secs. No Protection x 10^2 seconds	135° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds
37.5 : 75	125	3.8	0.6	131	1.9	0.3
75 : 150	123	2.3	0.6	129	1.2	0.3
150 : 300	122	1.5	1.9	128	0.7	0.9
300 : 600	119	1.6	26.0	128	0.6	3.4
600 : 1,200	117	1.5	68.0	127	0.5	5.9
1,200 : 2,400	114	1.7	-	125	0.5	9.0
2,400 : 4,800	111	2.0	-	121	0.6	82.0
4,800 : 9,600	109	2.4	-	117	0.9	21.5

Octave Band Cycles/sec.	157½° Sound Pressure Level dB	157½° Safe Endurance Time - Secs. No Protection x 10^2 seconds	157½° Safe Endurance Time - Secs. Wearing Ear-Defenders x 10^3 seconds
37.5 : 75	129	2.4	0.4
75 : 150	127	1.5	0.4
150 : 300	125	1.0	1.35
300 : 600	122	1.1	13.0
600 : 1,200	118	1.3	48.0
1,200 : 2,400	121	0.8	23.0
2,400 : 4,800	117	1.0	-
4,800 : 9,600	114	1.4	43.0

A method of estimating noise doses

A hearing damage risk criterion has been published by Professor Burns and this has been made the basis for our determination of the maximum permissible exposure times to aircraft noises at various sound pressure levels and frequencies. The criterion is given in Table 1 and 2 of the text.

This appendix details how the noise dose estimates were calculated and the assumptions which have been made, namely:-

(i) The criterion may be presented in graphical form and the resulting curves hold for octave band centre frequencies other than those given in the criterion.

(ii) The criterion may be extended to cover exposure times greater than eight hours and less than 7½ minutes, subject to an upper limit of 135 dB.

(iii) The effects upon the ear of noises in adjacent octave-bands are independent of one another and are not additive.

Further to assumption (ii), the Burns' criterion has been drawn up to regulate the loss of hearing which occurs when people are exposed to high ambient noise levels during working hours, and it is based upon an eight hour working day. In the case of short exposure times (very high noise levels), it is unlikely that these will be encountered regularly or frequently by individuals not wearing ear protection and, therefore, the extrapolation is reasonable for people who are in transit about the airfield or whose duties take them into positions where they might experience very loud noise by chance.

Noise Dose Estimation

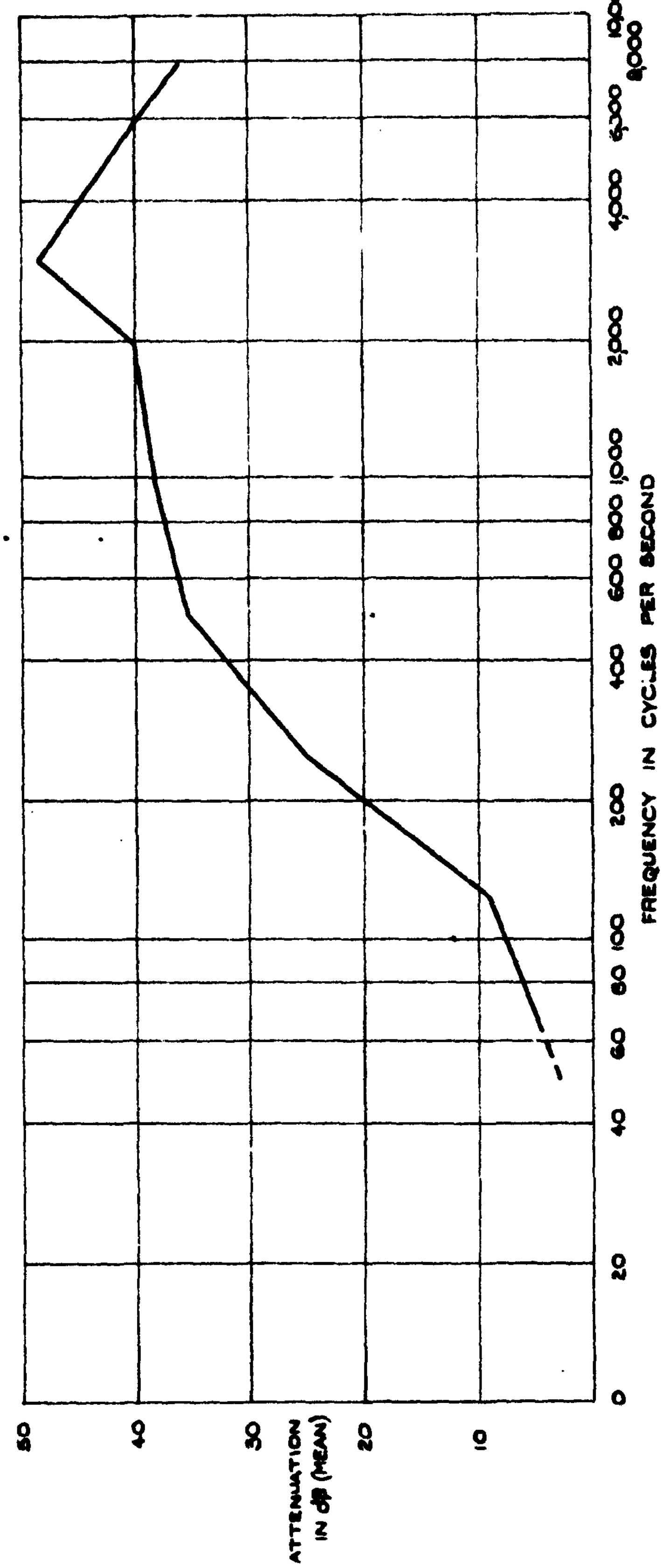
A Pegasus computer was used to calculate the sound pressure levels at an observer standing beside the runway and to estimate the proportion of a day's noise dose accounted for at each position. The proportion of the total sound energy propogated in any given direction relative to the aircraft centre line was taken to be the same as for stationary engine running with after burner and the results published in ref. A. & A.E.E. Tech/281/Eng were used as the basis for computation together with kinetheodolite readings of time and distance taken during the take-off of the T.S.R.2.

The noise doses likely to be experienced by the observer have been estimated by dividing the areas under each of the curves into half-second intervals and using the Burns' criterion to determine the time of exposure required to use up a whole day's noise ration at the noise level prevailing during each interval.

The total noise dose was then obtained by dividing these values in the 0.5 secs. and summing for the whole period of the take-off. The critical octave band for ear damage was established as being the 1.8 kc. one by detailed manual analysis of the take-off tape recordings. However, as further experimental results may show that other bands contribute to the noise dose at different positions of the observer, this method of noise dose estimation should be regarded as being a provisional one.

Tables V and VI show the computing of the safe endurance time for various positions around the 100 yds. circle at the engine running site.

FIG.1.



SK. Nº B3031 TECH/300/ENG.

ATTENUATION IN dB V. FREQUENCY BAND IN C/S FOR MK.III EAR-DEFENDERS. OBTAINED FROM REPORT C.M.E. C.3061/101/1 ENTITLED EAR PROTECTION IN INTENSE NOISE FIELDS. PT. I. FEB. 1964 BY WG. CDR. J. A. WHEELER-BENNETT. M.R.C.S., L.R.C.P., D.P.H.

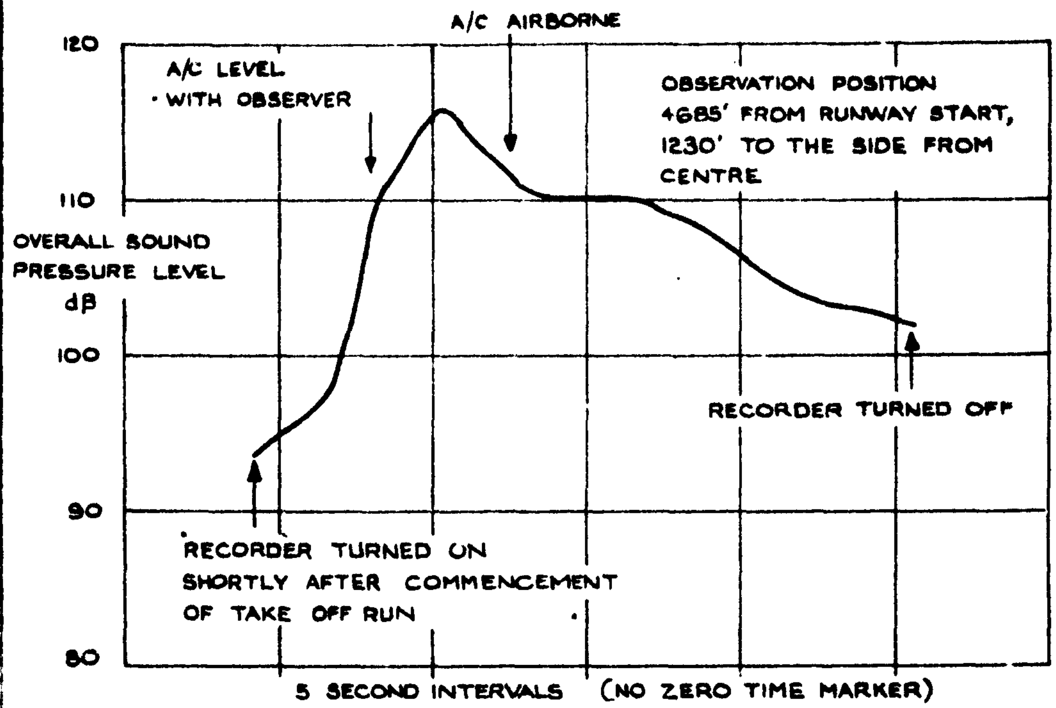


FIG. 2. SMOOTHED CURVE FROM RECORDING OF NOISE DURING TAKE-OFF.

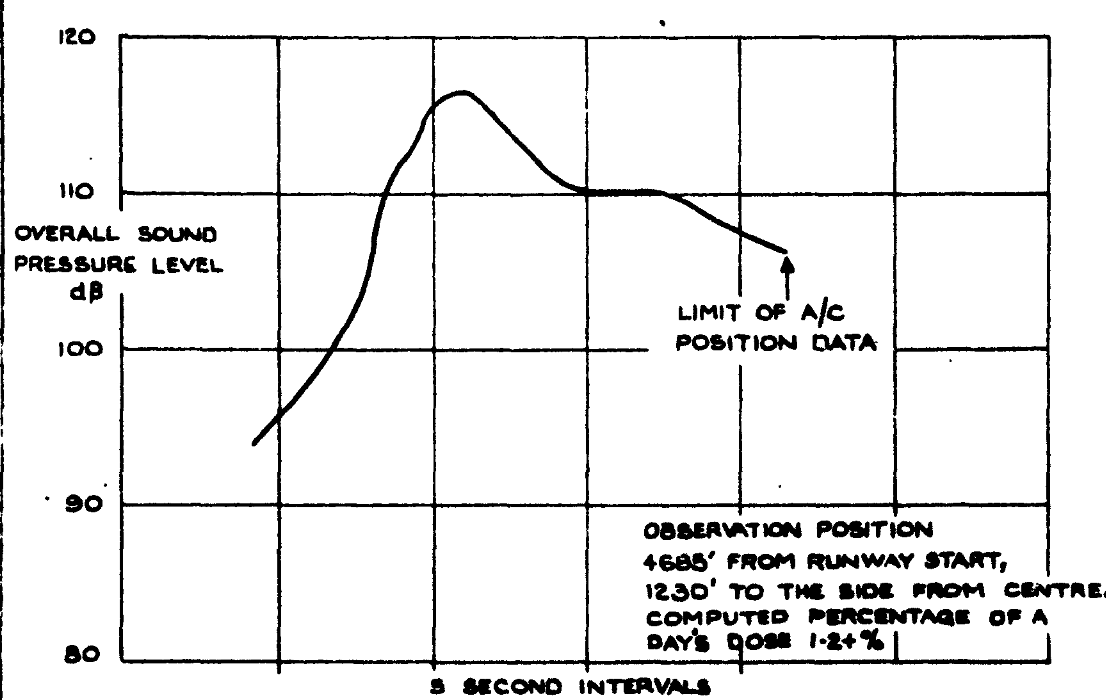


FIG. 3. COMPUTED OVERALL SOUND PRESSURE LEVELS FOR THE TAKE-OFF OF FIG. 2.

FIGS. 4 & 5.

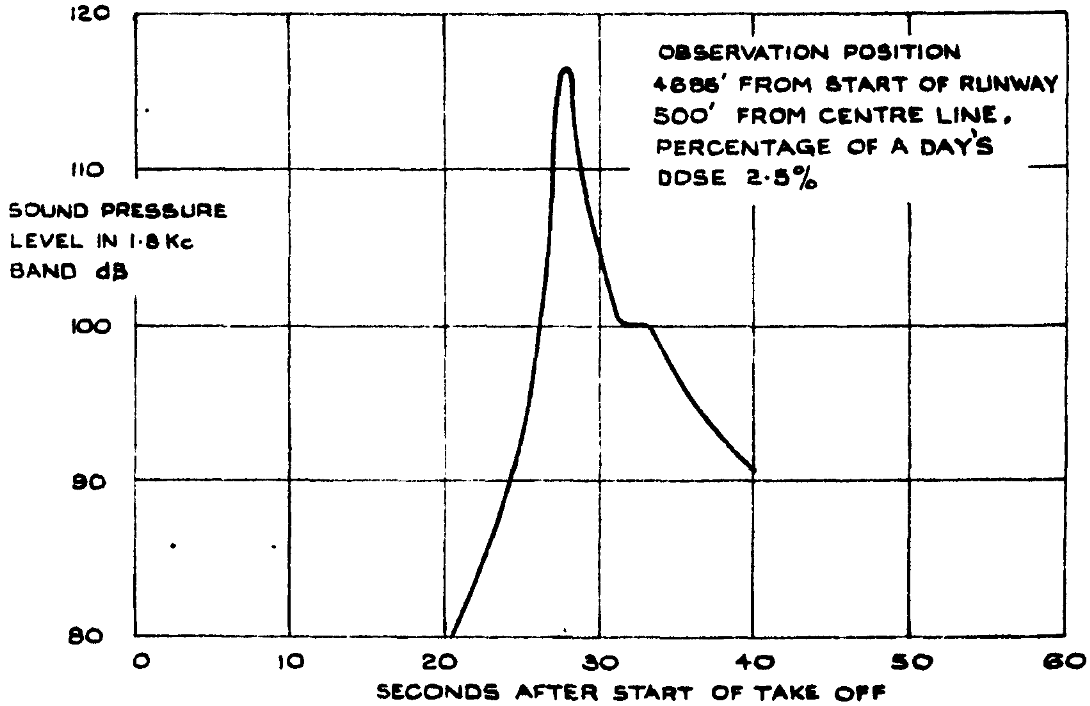


FIG.4. COMPUTER ESTIMATED SOUND PRESSURE LEVEL.

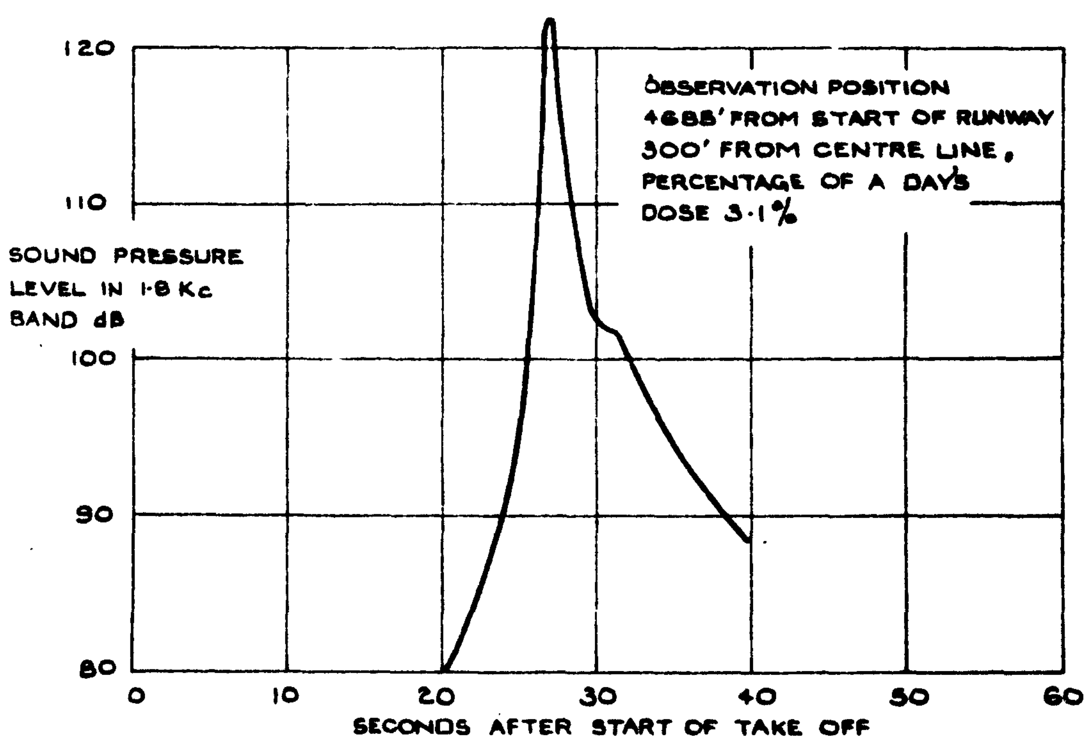


FIG.5. COMPUTER ESTIMATED SOUND PRESSURE LEVEL.

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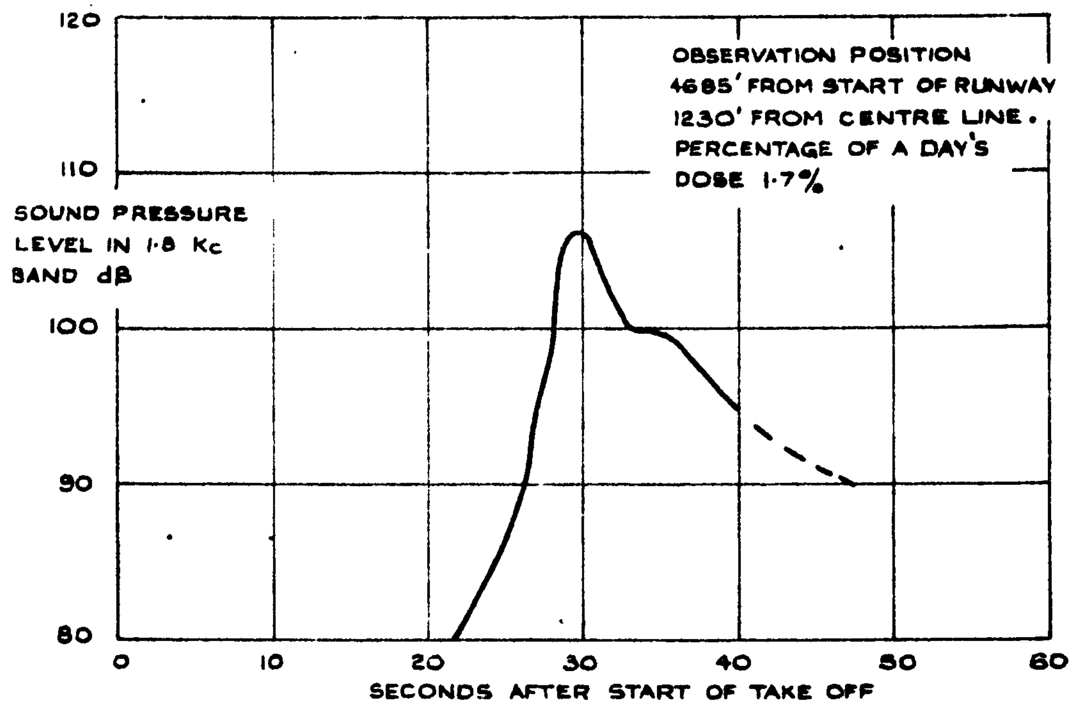

FIG. 6. COMPUTER ESTIMATED SOUND PRESSURE LEVEL.

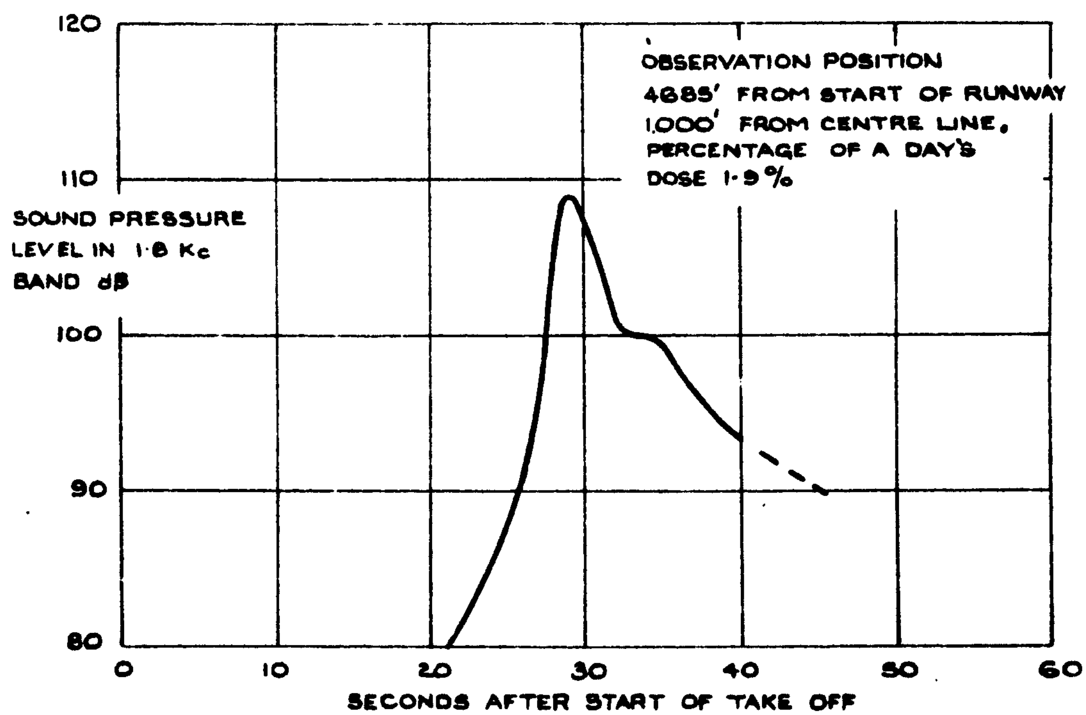

FIG. 7. COMPUTER ESTIMATED SOUND PRESSURE LEVEL.

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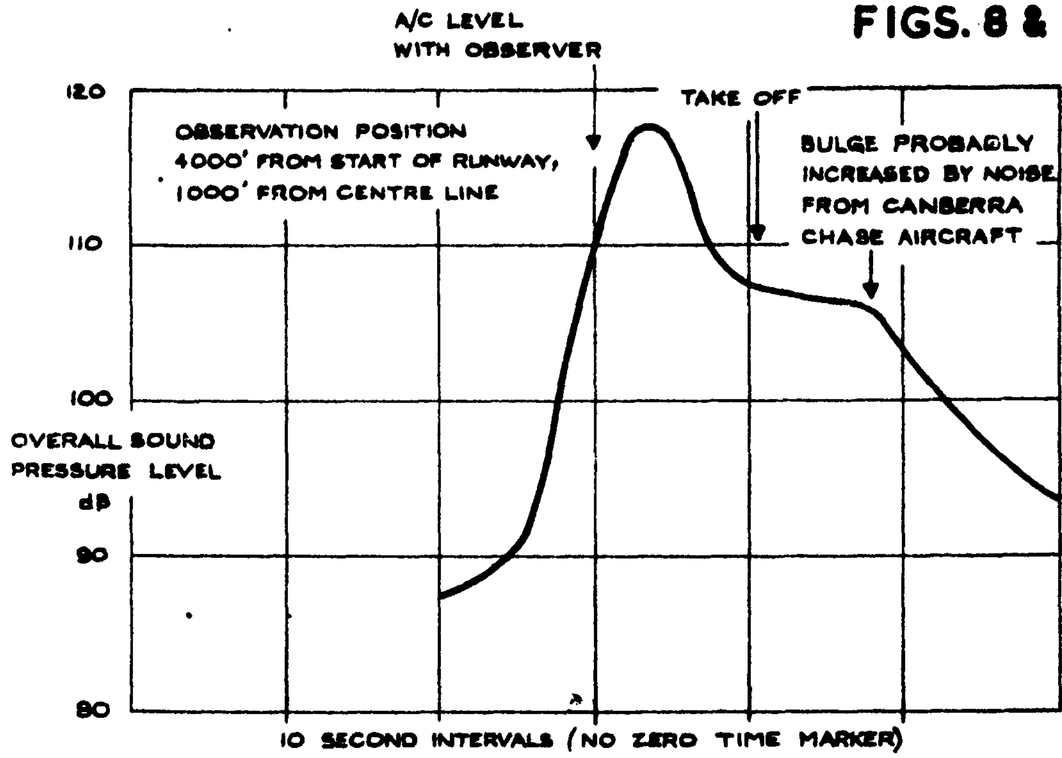


FIG. 8. SMOOTHED CURVE FROM RECORDING OF 6TH TAKE OFF

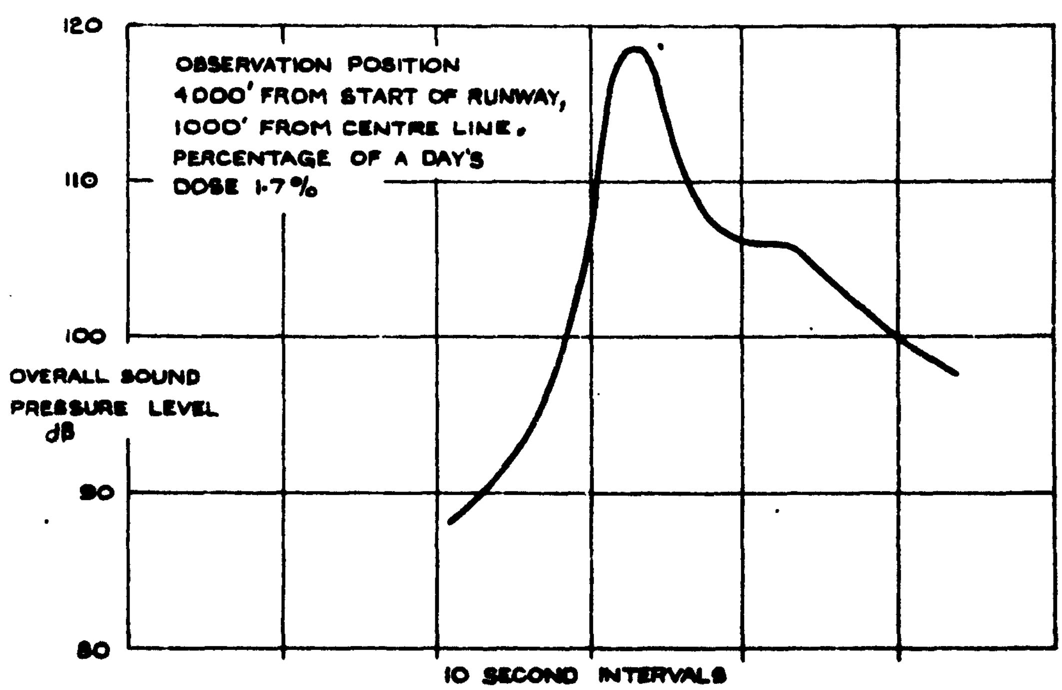


FIG. 9. COMPUTER ESTIMATE FOR 6TH TAKE OFF.

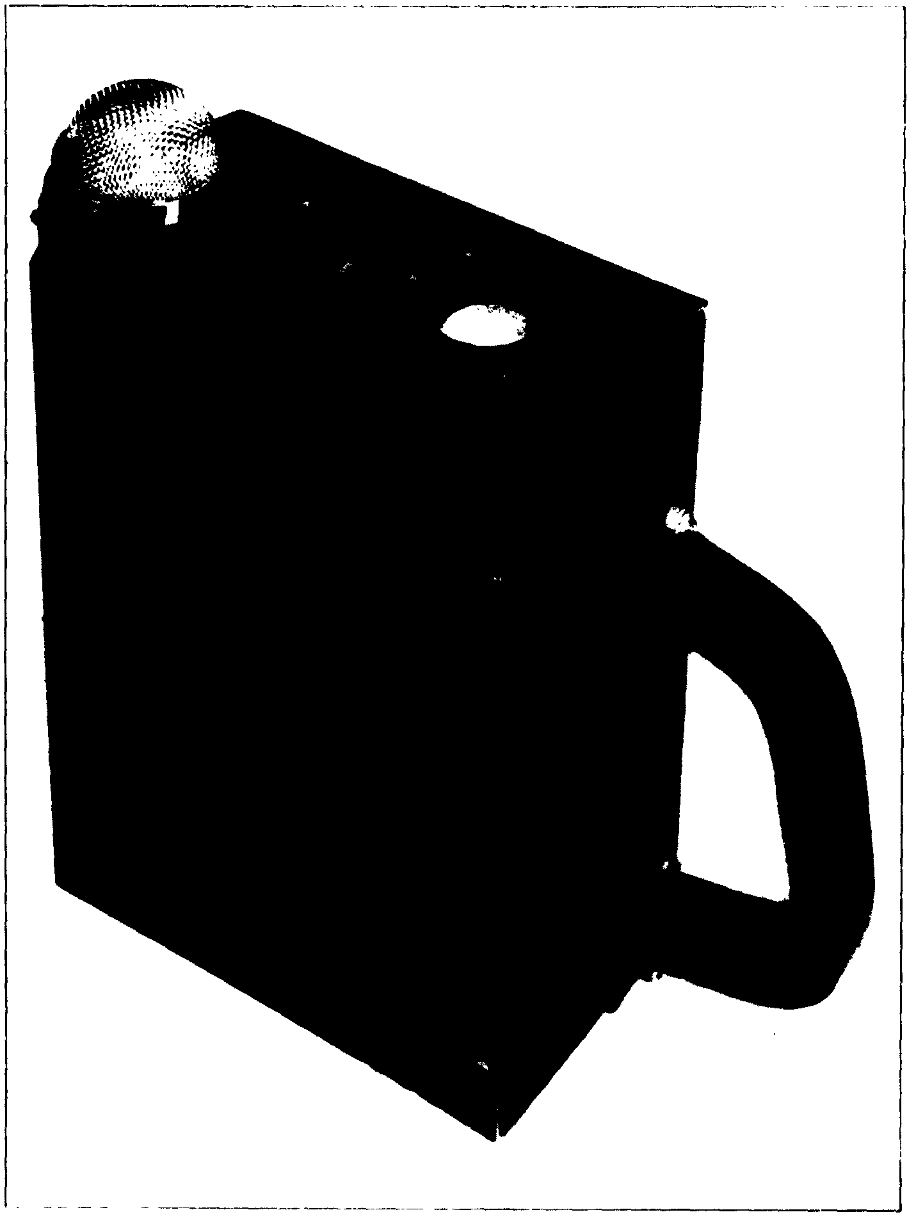
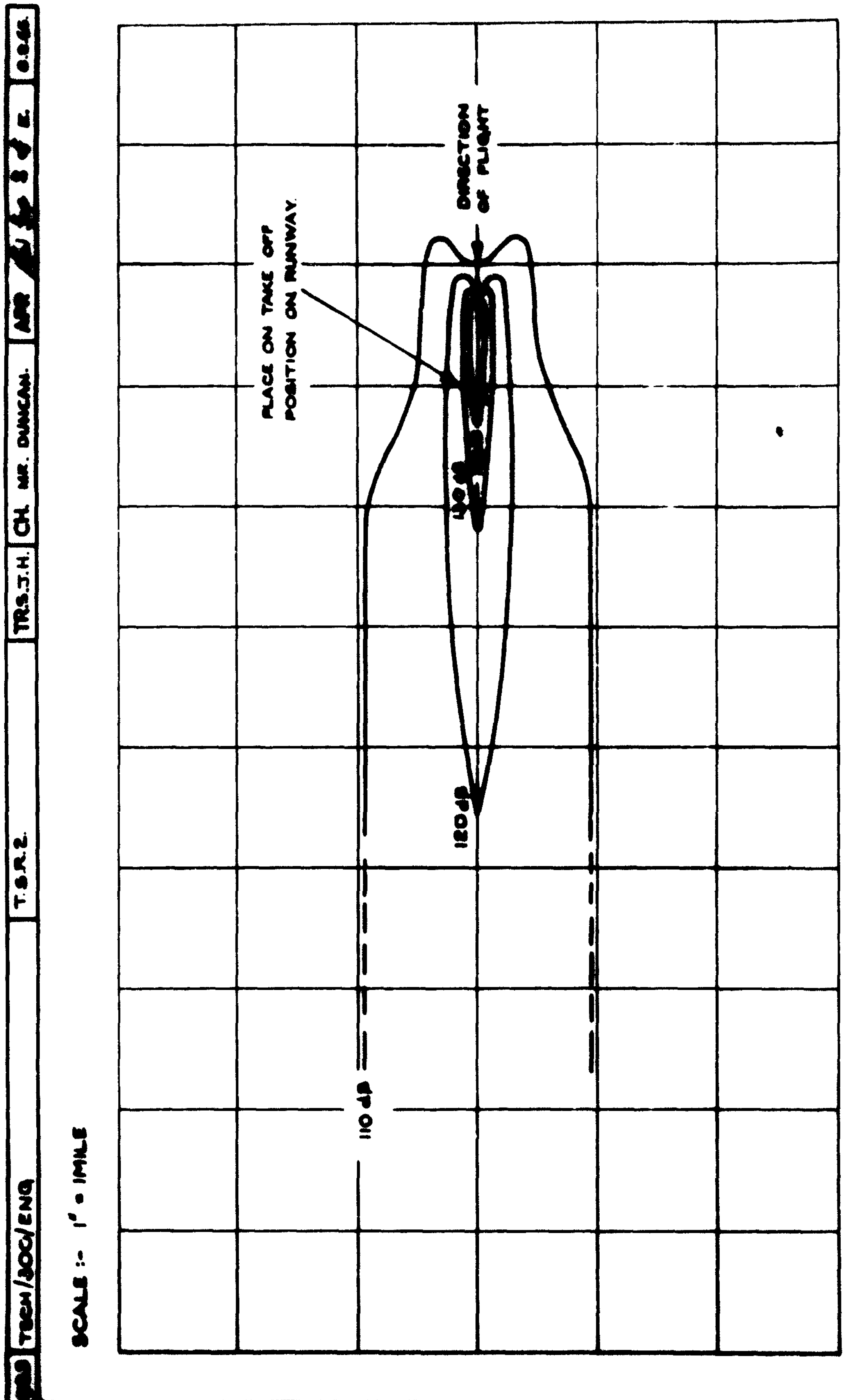
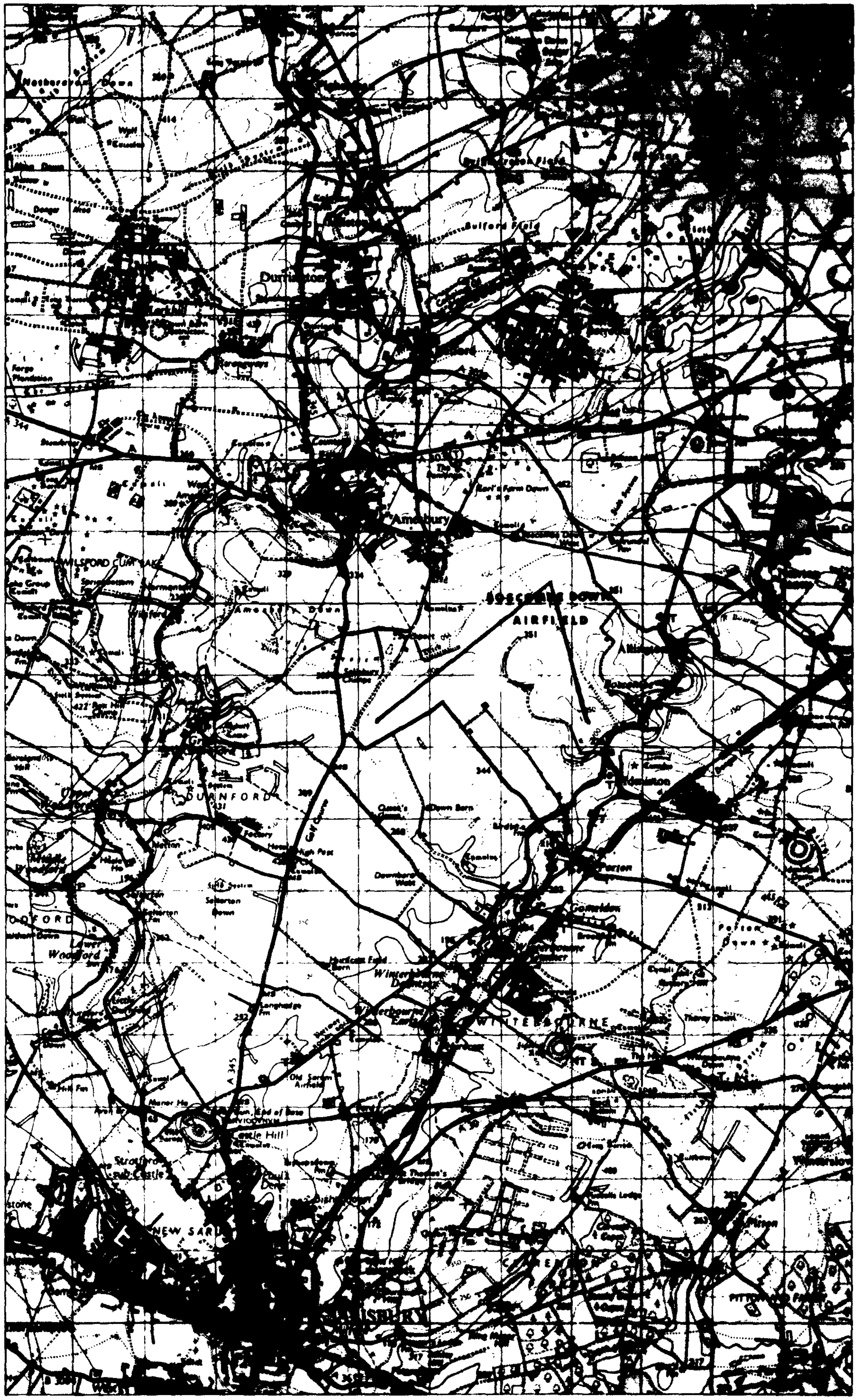


FIG. 10. PROTOTYPE NOISE DOSE METER.



[illegible] OF SOUND PRESSURE LEVELS SWEPT OUT OVER THE [GROUND] IN A HYPOTHETICAL EMERGENCY LOW RATE OF CLIMB WITH REHEAT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Date of Search: 12 February 2009

Record Summary: DSIR 23/33495
Noise hazard associated with aircraft with particular reference to TSR 2 at Boscombe Down (Rep AAEE/Tech/300/Eng)
Former reference (Department): ARC 27658
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